*Combustion, Explosion, and Shock Waves, Vol. 36, No. 6, 2000*

# Development of the First Nuclear Charge RDS-41 (11D) for Artillery Projectile

**V. P. Zhogin**[*]

Translated from *Fizika Goreniya i Vzryva*, Vol. 36, No. 6, pp. 14–20, November–December, 2000.

## EDITORIAL

In the early 1950s, all publications concerning M. A. Lavrent'ev showed some reticence. Sometimes, one could read a phrase typical of that time: "... took part in the creation of the nuclear shield of the Motherland ... ." Mikhail Alekseevich was even more reserved: "I worked with Igor' Vasil'evich Kurchatov ... ." The situation was not clearer when Lavrent'ev's work in Design Office-11 (DO-11) [at present the Institute of Experimental Physics (IEP) of the Russian Federal Nuclear Center] was mentioned in the well-known book *The Soviet Atomic Project* [Academician Ye. A. Negin (ed.), Izd. "Nizhnii Novgorod," Arzamas-16–Nizhnii Novgorod (1995), p. 195]. The article by Lavrent'ev's former (DO-11) colleague Vasilii Petrovich Zhogin (unfortunately deceased) is likely to be the first to raise the old veil of secrecy.

We should mention at least something about the appearance of the manuscript on the editor's desk and about its author. The spring months of 1998 and 1999 were marked by the jubilees of two well-known, excellent scientists, Lavrent'ev's colleagues (DO-11) Academicians D. V. Shirkov and L. V. Ovsyannikov. They were 70 and 80, respectively. As these dates almost coincided with the fortieth anniversary of the awarding of the Lenin Prize for the creation of the first domestic atomic artillery projectile of original design, it was decided to hold a seminar dedicated to these dates in Novosibirsk Akademgorodok. V. P. Zhogin agreed to give a talk at the seminar. The present paper is based on the supposed text of his speech.

It turned out to be impossible to collect scientists from different towns and cities within a short period of time. But at the end of 1998 Vasilii Petrovich died of a sudden asthma attack. His manuscript, ready for publication, was in Akademgorodok.

While preparing the jubilee issue of the Journal, the editorial board found it reasonable to publish the paper. Colleagues from the IEP did some editing (mainly decoding some technical abbreviations) and obtained permission for its publication. Thus, this paper appears on our pages.

The author of the article (in the last years of his life) Vice-Chief designer of the IEP, by the words of his colleagues, was an outstanding designer and an extraordinary personality. In addition, just after graduation from the Moscow Road Transport Institute (!), he was lucky to start his working career in the young collective body headed by M. A. Lavrent'ev. His colleagues describe the beginning of his creative way in science as follows [G. B. Ivanov, "The Zhogin Phenomenon," *Gorodskoi Kur'er*, December 9 (No. 49), Sarov (1999), p.10]: "Having graduated from the Moscow Road Transport Institute with credit, the young specialist V. Zhogin returns to his native closed town Sarov and enters the group developing the first atomic artillery projectile. The team was headed by Academician M. A. Lavrent'ev, an outstanding mathematician and mechanician, who was later awarded the Order of the French Legion of Honour, its rare kind "Komandor."

Work on the artillery projectile in the designers' team under the supervision of A. I. Abramov, a unique artillery designer, and V. M. Nekrutkin, a skillful shotfirer, soon changed the young specialist in road transport into a pioneer in the field of domestic atomic artillery. Here he showed an unbounded readiness to work in the new field and an aspiration to start something new, to belong to the avant-garde, to be among experienced specialists and to learn from them. The tense work of the young team ended in the spring of 1956 with the test site experiment of the first domestic (the world's first from the viewpoint of design) atomic artillery ammunition. It was a trial in which 26-year old Vasilii Zhogin was actively participating. The result of this trial was so important that the team of implemen-

---

[*] Deceased.

0010-5082/00/3606-0689 $25.00 © 2000 Plenum Publishing Corporation

tors with Academician M. A. Lavrent'ev as its leader became Lenin Prize winners in 1958. This Prize was introduced anew and was the second after Kurchatov, Zel'dovich, Sakharov, and Khariton. Zhogin's supervisor, A. Abramov, became the first winner of this Prize among the designers of the project.

The enthusiastic, tireless Zhogin soon "got into" the new direction of research and, together with A. Abramov, P. Ishkov, and others, changed his "artillery face" and turned to the so-called "light gas" direction, inspired by theoreticians and gas dynamics professionals, and achieved much success in this field. The 29-year old Vasilii Zhogin was among the eleven Lenin Prize winners in 1959.

V. P. Zhogin was and remains the youngest Lenin Prize winner in the celebrated IEP. The second reward — the State Prize — was awarded to him in 1969, when he was head of a department. And in the beginning of 2000 he would be seventy . . . .

The article in the Sarov newspaper dedicated to the anniversary of V. Zhogin's death acknowledges his talents and his thirst for creation and ends with the words: "... V. Zhogin had a complicated and contradictory personality but, undoubtedly, was a skillful designer. He was completely involved in his work, and even his death was in its way symbolic — he died on his way to his business mission. The Zhogin phenomenon should be studied and, more importantly, be remembered."

The editors of the Journal express their gratitude to A. G. Ivanov, a principal researcher, and G. V. Ivanov, Head of the Laboratory (IEP), for their help in preparing this material and to R. I. Il'kaev, Corresponding Member of the Russian Academy of Sciences, Director of the IEP, for his assistance in obtaining permission to publish this material.

*V. M. Titov*

## 1. HISTORY OF THE ISSUE

After the trial of the first domestic nuclear charge RDS-1 on August 29, 1949, the U.S. nuclear weapons monopoly ended, and both countries entered a new epoch — the arms race epoch — aimed at securing approximate nuclear parity on the part of the USSR and at securing advantage in possessing new nuclear armaments on the part of the U.S.

The task to develop a nuclear charge for an artillery projectile was posed by the middle of 1952. To implement this task, a specialized subdivision — Sector 11 — was founded.

The formulation of this task in the USSR was undoubtedly due to the fact that work on the creation of a nuclear artillery projectile was already in progress in the U.S. at that time. Nuclear artillery depends insignificantly on weather conditions and must provide high tactical efficiency to the infantry, the navy, and the marines. It was in 1950 when the formulation of tasks intended for the development of the charge for the artillery of the infantry and the navy began. In the U.S., the range nuclear test of the first nuclear charge MK-9 of diameter 280 mm (11 inches) was conducted on May 25, 1953, and by that time, the first special weapon had been made. It weighed 93 tons, and its total length with the transporting mechanism was about 79 feet, with a firing range of about 14 miles. From 1953 to 1986, eight articles of artillery projectiles with nuclear charges having size from 406 mm (16 inches) to 155 mm ($\approx$6.1 inches) were developed in the U.S. The first four types of charges for projectiles were developed on the basis of the physical scheme "guns rendezvous" with $U_{235}$ as the fissionable material. Although this scheme is very suitable from the viewpoint of strength and size, it has a very small efficiency and, hence, requires large expenditures of $U_{235}$.

It should be noted that by the time Sector 11 was organized (the end of 1952), DO-11 had been developing nuclear charges having sizes more than twice as large as the size needed for the artillery and three orders of magnitude less strong than needed. The immensity of the formulated task had become evident.

## 2. BEGINNING OF WORK

Having realized serious difficulties in finding a successful solution to the task of developing the artillery projectile, the leaders of DO-11 asked Academician M. A. Lavrent'ev, a well-known scientist, for direction. Thus, M. A. Lavrent'ev became the scientific supervisor of Sector 11 engaged in the development of a nuclear charge for an artillery projectile.

V. M. Nekrutkin was appointed head of the sector, where he combined this job while heading one of the gas-dynamics departments. The sector comprised the following subdivisions (since 1953):

1. Theoretical Design Department

   — theoreticians D. V. Shirkov, L. V. Ovsyannikov, and S. V. Iordanskii in close cooperation with the Department of Applied Mathematics of the USSR Academy of Sciences and departments headed by P. I. Chushkin and A. A. Samarskii;

— a team of professionals in strength of materials: L. A. Galin, F. A. Sokolov, A. M. Germanov, D. A. Panin, and others.

2. The gas Dynamics Department headed by V. M. Nekrutkin included B. N. Ledenev, A. T. Zavgorodnii, I. V. Dorozhkin, F. V. Grigor'ev, and Yu. F. Alekseev (in 1955, V. P. Ratnikov and L. L. Lebedev moved to DO-1011), B. V. Voitsekhovskii, A. S. Kozyrev, and A. D. Makarov.
3. The gas Dynamics Department headed by L. V. Al'tshuler included S. B. Kormer, M. N. Pavlovskii, S. N. Pokrovskii, M. V. Sinitsyn, A. M. Bakanova, M. I. Brazhnik, K. K. Krupnikov (K. K. Krupnikov and S. N. Pokrovskii moved to DO-1011), and others.
4. The design Department headed by A. I. Abramov included P. D. Ishkov, M. I. Puzyrev, M. A. Bibikin, and S. A. Krivov and, from 1953, V. P. Zhogin, F. F. Zhelobanov, V. N. Finashin, and N. N. Kriul'kin. Later the last three and M. A. Bibikin moved to DO-1011. In 1955 M. A. Savel'ev, Yu. Ya. Kozichev, B. N. Bukin, V. N. Maslov, A. S. Florov, and L. V. Karpov joined the Department.
5. Automatics Systems Department.

In spite of the fact that by the end of 1952 there were some ideas on ways of designing the charge (D. M. Tarasov's report at the Scientific-Technical Council of DO-11), the work started with choosing a physical scheme and the size of the charge.

For two years (1953–1954), a large number of combinations of various sizes and physical schemes were studied to determine the basic parameters of the charge and its external ballistics. First, charges for projectiles of different sizes constructed on the "implosion" principle were developed based on the following physical schemes:

— "cucumbers" using a special focusing system;

— "scatters" — a scheme with a liquid high explosive (HE) in which the charge placed in the projectile body is stretched into a cylinder to decrease its size. Initiation of the liquid HE is multipoint, from electric detonators.

The work started with the development of design-layout schemes of charges as part of the projectile body. From 1953, designers V. P. Zhogin, V. K. Rodnikov, N. N. Kriul'kin, F. F. Zhelobanov, and V. N. Finashin were involved in this work.

After discussions with M. A. Lavrent'ev of P. D. Ishkov's report on the impossibility of providing a proper external ballistics of artillery projectiles with charges of the types considered, the work was interrupted. As a result of this research, adequate computational techniques were developed, and the young designers gained good experience in this new field of knowledge.

## 3. RDS-41 CHARGE

It was by the end of 1954 when a charge design with a heavy body and multipoint initiation was selected — the RDS-41 charge. Then work on the choice of the size of the charge and elements of its external ballistics began.

The requirements of high strength did not permit using in DO-11 the approaches worked out earlier:

(a) the special focusing system (in particular, because of its overly large dimensions);

(b) TNT–RDX explosive composition;

(c) installation of the central unit without supplementary load-bearing elements;

(d) fixing the charge components by the "dense assembly" principle.

In the RDS-41 charge, all units were redeveloped and it was of original design from the body to the neutron source.

The charge was designed using high-strength HE, a focusing crashproof system, load-bearing parts of the charge made of high-strength steel, and new fissionable materials.

The charge configuration was developed in A. I. Abramov's Department. Part of the structure (excluding the central unit) was elaborated by the group of P. D. Ishkov, M. A. Bibikin, and V. N. Finashin. The focusing system was developed by V. P. Zhogin. C. A. Krivov worked on the gas dynamics blocks. Electric detonators were elaborated by M. I. Puzyrev's team. The neutron source was designed by A. I. Abramov. L. V. Karpov worked on the assembly and disassembly equipment.

All my life I remember a terrible night at the beginning of 1955. I dreamed of a tracing of the focusing system with dozens of cuttings and hundreds of sizes, and suddenly I saw 40° instead of 45° at the coordinate angle of the fire-set point. I woke up in cold sweat as I knew that the first parts were being produced at the plant. Early in the morning I ran to the special department, took the tracing paper, and saw the figure of 40° — that was a mistake! I ran to the shop. Fortunately, this operation had not been done as yet. I reported the mistake to the chief of the department A. I. Abramov, and permission for the change was issued. The mistake was corrected, and we escaped the consequences of the defect. Later I often invented something in my dreams, but only once did I see a mistake in my dream.

The artillery ammunition was designed in cooperation with the Artillery Design Offices (DO) and Scientific-Research Institutes (SRI). Thus, the projectile body and the artillery ammunition as a whole were constructed together with SRI-24 (Chief designer I. P. Dzyuba), the dynamoreactive gun was developed with the Central SRI-58 (Chief designer V. G. Grabin), a special gun was designed with Central DO-34 (Chief designer I. I. Ivanov), and the mortar was elaborated with the DO of Mortar Systems (Chief designer B. I. Shavyrin).

Especially tight cooperation existed with the Central SRI-58. Together we formulated an elaborate program of mastering ammunition parts by means of gun-firing on the artillery range of the SRI. S. E. Bardenshtein supervised this program on behalf of the Central SRI-58.

## 4. TESTS OF EXPLOSIVE CHARGE AND ITS ELEMENTS

The main part of the charge was its heavy body containing a strength element, a focusing system, and an element raising the efficiency of the explosive charge.

Gas-dynamic tests of the charge was supervised by V. M. Nekrutkin, by leading specialists B. N. Ledenev, A. T. Zavgorodnii, I. V. Dorozhkin, M. P. Speranskii, V. P. Ratnikov, F. V. Grigor'ev, and others. Tests of the focusing system were carried out in parallel with investigations of the symmetry of detonation-wave convergence and the efficiency of explosive charge operation. Development of the new high-strength and powerful explosives was conducted by a group of scientists headed by A. S. Kozyrev, including Yu. F. Alekseev, L. L. Lebedev, and A. D. Makarov together with specialists from Plant No. 2 under the supervision of A. M. Komarov and B. M. Glazkov.

As a result, a thermostable explosive composition was chosen for use in the charge. After a series of examinations, it was tested on the range of the Central SRI-58 by gun-firing of 2000 37-mm rounds to check their resistance to explosion.

In these investigations, many original methods and arrangements were proposed, which raised the quality of the design. It suffices to mention the "big ballistic pendulum" installed on site 2.

The history of creation of the pendulum is the following. M. A. Lavrent'ev calls A. I. Abramov and asks to send him a designer. This designer was me. I go out from building No. 32a and see auto ZIM, and M. A. Lavrent'ev invites me to get in. We arrived at the site near a casemate where there were three welders. Nearby there was a plate weighing about 200 kg, a tube, and some rods. M. A. Lavrent'ev said that the tube was to be installed between the nearest lime-trees and upon this tube the plate should be suspended — this would make a big ballistic pendulum, the biggest in the USSR. The essence of the matter was in some proper calculation of the circular bends of the rods that held the plate suspended on the tube. The diameter was to be such that with deflection of the plate through an angle of 40°, the ring of the rod was to keep on rolling on the tube without sliding, i.e., providing rolling friction. Within the next 3–4 hours, the pendulum was brought into operation. In a few months, while discussing the work, M. A. Lavrent'ev said jokingly that the pendulum had proved to be "the most precise."

The shock-wave compression of the charge elements and its effectiveness were studied by the Department headed by L. V. Al'tshuler and also by S. B. Kormer, K. K. Krupnikov, M. N. Pavlovskii, A. M. Bakanova, M. I. Brazhnik, and others. We were worried by "tears" (leading disturbances) that arose under the focusing system during operation of the charge. The solution of this problem took a lot of time. We succeeded in reducing the magnitude of disturbances and, as a result, their effect on the work of the charge proved to be permissible.

By the end of 1955, all numerical-theoretical and gas-dynamic studies had been completed and the RDS-41 charge had been prepared for range tests.

It was mentioned above that all theoretical calculations were made by D. V. Shirkov, L. V. Ovsyannikov, and S. V. Iordanskii with the participation of the Department of Applied Mathematics (DAM). Academician V. S. Vladimirov (some years later Director of the Steklov Institute of Mathematics) recollects this work: "In January 1955, I moved from the object to the Central SRI-58 not far from Moscow. M. A. Lavrent'ev expanded his work on the project. D. V. Shirkov and I were engaged in problems of neutron physics. All calculations were performed on "Strela" at the DAM and in A. A. Samarskii's department. L. V. Ovsyannikov and S. V. Iordanskii were solving compression and gas-dynamic problems. Calculations were done on a BÉSM-1 at the Institute of Precise Mechanics and Computer Science headed by S. A. Lebedev.

S. V. Vladimirov warmly recollects his creative cooperation with M. A. Lavrent'ev and his co-workers while working at the project of the RDS-41.

Studies of the structure strength, including calculations, played the most important role in the elaboration of the charge.

There were no test facilities, and, therefore, the design of various devices was started. Thus, for studies of dynamic actions, a 15-m high discharge tower was designed and installed. A disk centrifuge was constructed to study inertia effects of long duration. B. V. Voitsekhovskii led these developments on Lavrent'ev's instructions.

The static strength of the charge parts was tested mainly on the presses of block No. 26.

Here we should mention one episode which can be instructive for designers. In tests of the mechanical unit of the RDS-41, the load on the central unit was to be about 60 tons. At the same time, it was necessary to apply a small force to set zero on all movement indicators. It was agreed with A. I. Abramov that the force would be equal to 5 tons. But it turned out that this force was enough to disengage the metric thread of large diameter. The experiment failed. An analysis showed that axial loading in the metric thread gave rise to radial forces, and, with the small stiffness of unscrewing details, the thread slips. All threads were replaced by bands, and further experiments were successful.

Tests were performed mostly by gun firing on the range of the Central SRI-58 with:

— HE samples and electric detonators (from a 37-mm gun);

— models of all elements of the charge (from a 130-mm gun).

Gun firing was conducted as a rule against a barn covered with tow to preserve the models.

Test firing of the full-scale charge was carried out by real guns developed by that time at the Central SRI-58 and CDO-34 on the Rzhev artillery range.

The project meant to arrange two stages of tests: inert dummies first and models charged with HE. The tests with HE were carried out by projectiles supplied with parachutes developed by the Research Institute of Parachute Systems.

An interesting episode happened when two containers with inert dummies of the RDS-41 were to be transported from the Vnukovo airport to the Rzhev artillery range. The dummies were escorted by P. D. Ishkov and A. S. Firstov from DO-11, two representatives of the department of special storage (one of them with a case of documents), a guard officer, and three sub-machine-gunners. The team of loaders did not know how to load the heavy containers into the plane. However, when by means of laying some planks the loading was done, their master, calling P. D. Ishkov aside, told him that he knew what was inside the containers — that those were atomic bombs. Pavel Ishkov was shocked and asked what made him think so. The master said: "First, the containers are not big but very heavy. Second, you are four civilians and there are four sub-machine-gunners with you; besides, one of you does not let go of his case. There is an explosive device inside. This is an atomic bomb."

The tests proved the strength of the charge and the ammunition as a whole.

The tests were performed under the supervision of A. I. Abramov and with the participation of P. D. Ishkov, V. N. Maslov, M. S. Savel'ev, and A. S. Firstov.

## 5. CHARGE TEST ON THE RANGE UP-2 OF THE MINISTRY OF DEFENSE

A test of the RDS-41 charge was planned for March, 1956. The charge enclosed in a projectile was to be placed on the floor of a wooden hut.

It is known that at that time ammunitions were stored in a dismantled state and were set into the readiness state immediately before use or placed on the alert according to special instructions.

Work on charge assembly was conducted at the plant in building No. 3/3, site 3 on inert dummies by a special assembling team.

The assembly was supervised by A. I. Abramov, Head of the department, and the executives were V. P. Zhogin (senior engineer) and A. S. Firstov (worker-mechanician). The work was done under the supervision of V. N. Bologov (a representative of the Ministry of Defense).

In mid January, the ammunition, equipment, and the personnel went to the range by train. On arrival at the range, the ammunition was placed on the site where it was to be finally assembled. It took more than a month to get ready for the trial, and finally the trial was set for the 16th of March ("Ch"-Day).

Assembly of the RDS-41 was carried out on March 15 by a special mounting team in the presence of four artillery generals. While mounting was being done, an incident happened — a stud fixing the arrangement on the central unit broke. Dinner break was organized for the generals to have time to eliminate the defect. After dinner, the assembly was successfully completed. The ammunition was loaded on a truck and, escorted by cars, arrived at the test hut.

Early in the morning on March 16, A. K. Bessarabenko, two fitters, and V. P. Zhogin as the design office representative arrived to equip the device with electric detonators. The equipping operation was delayed for an hour (quite unexpectedly, the aluminum lids of the steel projectile body were jammed, and the projectile body required cooling with snow). Nevertheless, the installation of detonators was completed on time. A. I. Abramov was reprimanded for the defect in the device design.

Some hours later the device was detonated. The results of the test were beyond expectations. The charge exhibited the highest possible power.

## 6. COMPLETION OF THE PROJECT

After successful trials on the range UP-2 of the Ministry of Defense and completion of test firing from special guns on the Rzhev range the "Technical Project of the RDS-41 Charge" was worked out.

As the charge design was an important contribution to the State defense, this device was nominated for the Lenin Prize in 1957. However, the design team was awarded the prize in 1958 (it was the first Lenin Prize in DO-11). M. A. Lavrent'ev, D. V. Shirkov, L. V. Ovsyannikov, V. M. Nekrutkin, and A. I. Abramov became Lenin Prize winners.

As is known, in 1956–1957 rearmament of the Army was begun, and artillery was replaced by rockets; therefore, the RDS-41 charge did not go into commercial production but was returned for responsible storage.

After firing on the Rzhev range, special self-propelled artillery mountings designed by the Central DO-34 (Chief designer I. I. Ivanov) and the Central SRI-58 (Chief designer V. G. Grabin) were paraded on Red Square on November 7, 1957 (photograph in the newspaper "*Pravda*" of November 8, 1957).

In August 1956, Sector 11 was disbanded: A. I. Abramov's Department and the group of those calculating strength joined Sector 5; V. M. Nerutkin and L. V. Altshuler's merged with Sector 3.

M. A. Lavrent'ev, L. V. Ovsyannikov, and B. V. Voitsekhovskii started organization of the Siberian Division of the Academy of Sciences. D. V. Shirkov moved to Moscow.

The creative, selfless labor of senior experts in science and technology from Sector 11 resulted in the birth of young specialists who laid the foundations of new departments.

It was the experience in the creation of the RDS-41 that made it possible for S. B. Kormer and A. I. Abramov's teams together with V. A. Aleksandrovich's department and theoreticians Ya. B. Zel'dovich, B. D. Bondarenko, and V. G. Morozov to solve in the next year (1957) the most difficult problem — to prepare the first thermonuclear charge for testing. But this is a different story.